CLAIMS

1. An ultrasonic sensor for performing transmission or reception of an ultrasonic wave to a circumjacent space stuffed with a fluid, the sensor comprising:

an ultrasonic transducer (2, 12, 22, 32, 42, 52, 62, 72); and

a propagation medium portion (6, 6A, 6B, 6C, 6D, 6E, 6F, 6G) that is stuffed in a space between the ultrasonic transducer and the circumjacent space, for forming a propagation path of the ultrasonic wave.

2. An ultrasonic sensor for performing transmission or reception of an ultrasonic wave to a circumjacent space stuffed with a fluid, the sensor comprising:

an ultrasonic transducer (2, 12, 22, 32, 42, 52, 62, 72); and

a propagation medium portion (6, 6A, 6B, 6C, 6D, 6E, 6F, 6G) that is arranged between the ultrasonic transducer and the circumjacent space, for forming a propagation path of the ultrasonic wave,

wherein a density ρ_1 of the propagation medium portion, an acoustic velocity C_1 in the propagation medium portion, a density ρ_2 of the fluid that stuffs the space, and a sound velocity C_2 in the fluid that stuffs the space satisfy a relation expressed as $(\rho_2/\rho_1) < (C_1/C_2) < 1$.

3. The ultrasonic sensor as claimed in claim 2,

wherein the propagation medium portion has a first surface region (7) that faces an ultrasonic vibration surface of the ultrasonic transducer and a second surface region (8) that faces a flow that stuffs the circumjacent space, and the second surface region of the propagation medium portion is inclined with respect to the first surface region.

4. An ultrasonic sensor for performing transmission or reception of an ultrasonic wave to a circumjacent space stuffed with a fluid, the sensor comprising:

an ultrasonic transducer (42, 52, 62, 72);

a propagation medium portion (6D, 6E, 6F, 6G) that is arranged between the ultrasonic transducer and the circumjacent space, for forming a propagation path of the ultrasonic wave; and

a reflector (44, 54, 64, 74) that is arranged in contact with the propagation medium portion, for controlling the propagation path of the ultrasonic wave, wherein

a density ρ_1 of the propagation medium portion, an acoustic velocity C_1 in the propagation medium portion, a density ρ_2 of the fluid that stuffs the space, and a sound velocity C_2 in the fluid that stuffs the space satisfy a relation expressed as $(\rho_2/\rho_1) < (C_1/C_2) < 1$.

5. The ultrasonic sensor as claimed in claim 4, wherein the propagation medium portion has a first surface

region (7) that faces an ultrasonic vibration surface of the ultrasonic transducer, a second surface region (8) that faces a flow that stuffs the circumjacent space and at least one third surface region (45, 55) that is arranged between the first surface region and the second surface region in the propagation path of the ultrasonic wave and brought in contact with the reflector, and the second surface region of the propagation medium portion is inclined with respect to at least one of the first surface region and the third surface region.

6. The ultrasonic sensor as claimed in any one of claims 1 through 5, wherein a density ρ_1 of the propagation medium portion, an incident angle θ_1 of an ultrasonic wave to an interface between the propagation medium portion and the fluid that stuffs the circumjacent space, a density ρ_2 of the fluid that stuffs the circumjacent space, and an approach angle θ_2 of the ultrasonic wave from the interface to the fluid that stuffs the circumjacent space almost satisfy a relation expressed as $\rho_2/\rho_1 = \cot\theta_2/\cot\theta_1$.

7. The ultrasonic sensor as claimed in any one of claims 1 through 5, wherein the propagation medium portion is formed of a dry gel of an inorganic oxide or an organic polymer.

8. The ultrasonic sensor as claimed in claim 6, wherein a solid frame portion of the dry gel is made

hydrophobic.

9. The ultrasonic sensor as claimed in claim 7, wherein a density of the dry gel is not greater than 500 kg/m^3, and a mean pore diameter of the dry gel is not greater than 100 nm.

10. The ultrasonic sensor as claimed in any one of claims 1 through 5, comprising: an acoustic matching layer (3, 13, 23, 33, 43, 53, 63, 73) that is provided between the ultrasonic transducer and the propagation medium portion, for acoustically matching the ultrasonic transducer with the propagation medium portion.

11. The ultrasonic sensor as claimed in any one of claims 1 through 5, wherein the fluid that stuffs the circumjacent space is a gas having a density ρ_2 of not greater than 10 kg/m^3.

12. The ultrasonic sensor as claimed in any one of claims 1 through 5, wherein a direction of transmission or reception of an ultrasonic wave is almost parallel to the second surface region.

13. An ultrasonic flowmeter comprising:

a flow measurement section (304) having an inner wall that defines a channel of a fluid to be measured;

at least one ultrasonic transducer (301a, 301b) that is provided outside a channel space (309) enclosed by the inner wall (340) of the flow measurement section, for

performing transmission or reception of an ultrasonic wave; and

a propagation medium portion (303a, 303b) that is arranged between the ultrasonic transducer and the channel space, for forming a propagation path of the ultrasonic wave, wherein

a density ρ_1 of the propagation medium portion, an acoustic velocity C_1 in the propagation medium portion, a density ρ_2 of the fluid to be measured, and a sound velocity C_2 of the fluid to be measured satisfy a relation expressed as $(\rho_2/\rho_1) < (C_1/C_2) < 1$.

14. The ultrasonic flowmeter as claimed in claim 13, wherein

a plurality of ultrasonic transducers are provided,

a first ultrasonic transducer among the plurality of ultrasonic transducers is arranged so as to emit an ultrasonic wave to a second ultrasonic transducer of the plurality of ultrasonic transducers, and

the second ultrasonic transducer is arranged so as to emit an ultrasonic wave to the first ultrasonic transducer.

15. The ultrasonic flowmeter as claimed in claim 13 or 14, wherein

the propagation medium portion has a first

surface region (331) that faces an ultrasonic vibration surface of the ultrasonic transducer and a second surface region (332) that faces the channel space, and

the second surface region of the propagation medium portion is inclined with respect to the first surface region.

16. The ultrasonic flowmeter as claimed in claim 15, wherein

the first surface region of the propagation medium portion is inclined in a direction of flow velocity of the fluid to be measured in the channel space, and the second surface region is parallel to the direction of flow velocity of the fluid to be measured in the channel space.

17. The ultrasonic flowmeter as claimed in claim 15 or 16, wherein the second surface region of the propagation medium portion forms substantially no difference in level between the second surface region and the inner wall of the flow measurement section.

18. The ultrasonic flowmeter as claimed in any one of claims 13 through 16, wherein

the density ρ_1 of the propagation medium portion, an incident angle θ_1 of an ultrasonic wave to an interface between the propagation medium portion and the fluid to be measured, the density ρ_2 of the fluid to be measured, and an approach angle θ_2 of the ultrasonic wave from the

interface to the fluid to be measured almost satisfy a relation expressed as $\rho_2/\rho_1 = \cot\theta_2/\cot\theta_1$.

19. The ultrasonic flowmeter as claimed in any one of claims 13 through 16, wherein the fluid to be measured is a gas having a density ρ_2 of not greater than 10 $kg \cdot m^{-3}$.

20. The ultrasonic flowmeter as claimed in any one of claims 13 through 16, wherein the propagation medium portion is formed of a dry gel of an inorganic oxide or an organic polymer.

21. The ultrasonic flowmeter as claimed in claim 20, wherein a solid frame portion of the dry gel is made hydrophobic.

22. The ultrasonic flowmeter as claimed in claim 21, wherein a density of the dry gel is not greater than 500 kg/m^3, and

a mean pore diameter of the dry gel is not greater than 100 nm.

23. The ultrasonic flowmeter as claimed in any one of claims 13 through 16, comprising: a matching layer that is provided between the ultrasonic transducer and the propagation medium portion, for acoustically matching the ultrasonic transducer with the propagation medium portion.

24. The ultrasonic flowmeter as claimed in any one of claims 13 through 16, wherein a size of a channel space in the flow measurement section, the size being measured in a

direction perpendicular to a direction of flow velocity of the fluid to be measured, is not greater than a half wavelength of the ultrasonic wave at a center frequency in the fluid to be measured.

25. The ultrasonic flowmeter as claimed in any one of claims 13 through 16, wherein the ultrasonic transducer forms a convergence sound field.

26. The ultrasonic flowmeter as claimed in claim 24, wherein the first surface region of the propagation medium portion (308a, 308b) is curved so as to form a lens surface.

27. An ultrasonic flowmeter comprising:

a flow measurement section (304) having an inner wall that defines a channel of a gas;

a pair of ultrasonic transducers (301a, 301b) that are provided outside a channel space (309) enclosed by the inner wall (340) of the flow measurement section, for performing transmission or reception of an ultrasonic wave; and

a pair of propagation medium portions (303a, 303b) that are arranged between each of the one pair of ultrasonic transducers and the channel space, for refracting a propagation path of the ultrasonic wave,

the propagation medium portion comprising a first surface region (331) that faces an ultrasonic vibration surface of the ultrasonic transducer and a second surface

region (332) that faces the channel space,

the first surface region of the propagation medium portion being inclined in a direction of flow velocity of the gas in the channel space, and the second surface region being almost parallel to the direction of flow velocity of the gas in the channel space.

28. An apparatus comprising:

the ultrasonic flowmeter claimed in any one of claims 13 through 16;

a pipe (304) for supplying a fluid to be measured to the ultrasonic flowmeter; and

a display section (703) for displaying a flow rate measured by the ultrasonic flowmeter.

29. An ultrasonic sensor for performing transmission or reception of an ultrasonic wave to a circumjacent space stuffed with a fluid, the sensor comprising:

an ultrasonic transducer (2, 12, 22, 32, 42, 52, 62, 72); and

a propagation medium portion (6, 6A, 6B, 6C, 6D, 6E, 6F, 6G) that is stuffed in a space between the ultrasonic transducer and the circumjacent space, for forming a propagation path of the ultrasonic wave, wherein

the propagation medium portion has a first surface region (7) that faces an ultrasonic vibration surface of the ultrasonic transducer and a second surface

region (8) that faces a flow stuffing the circumjacent space, and the second surface region of the propagation medium portion is inclined with respect to the first surface region.